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STATION PAPER NO. 7 MAY 1947

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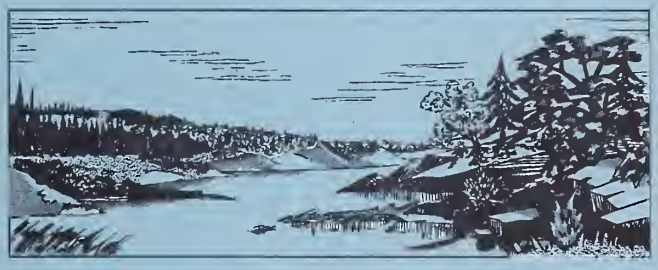

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DIVISION OF FOREST MANAGEMENT

LAKE STATES FOREST EXPERIMENT STATION

UNIVERSITY FARM, ST. PAUL 1, MINN.

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U. S. Department of Agriculture, Forest Service
Lake States Forest Experiment Station[1]

Station Paper No. 7 May 1947

GROWTH AND YIELD OF JACK PINE IN THE LAKE STATES[2]

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INTRODUCTION

During the past 30 years, jack pine in the Lake States climbed from obscurity to economic prominence. Once commercially unimportant, it is now used extensively in the production of pulpwood, box lumber, mine timbers, cabin logs, piling, poles, and posts. The growth and yield of this species is therefore of interest to forest managers and timberland owners.

According to the Forest Survey,[3] the present total area of jack pine in the Lake States is slightly over 3 million acres. The present total merchantable volume is estimated at 12 million cords. The total merchantable volume includes over 5 million cords of pulpwood and 2 billion board feet of sawlogs. The remaining 1 2/3 million cords are substandard cordwood.

The current annual growth of jack pine in the Lake States is in the neighborhood of 45 million cubic feet, or about 15 cubic feet per acre per year. This is only one-third of what can be produced under favorable conditions of stocking. Depending on age and site, a fully stocked acre of jack pine land should grow from 25 to 85 cubic feet per annum.

The heavy demands of the wood-using industries have already decreased the available supply of merchantable jack pine. Some central Wisconsin pulp mills are shipping lodgepole pine from Montana at a freight cost of $10.50 per cord. Consequently both the forester and the wood-user should know how to determine growth possibilities of the present merchantable stands and what to expect from young unmerchantable forests not yet of usable size.

1/ Maintained at University Farm, St. Paul, Minnesota, in cooperation with the University of Minnesota.

2/ Based on a paper delivered at the Operations-Research Conference of the Soil Conservation Service held on March 12, 1947, in Milwaukee, Wisconsin.

3/ Revised Forest Statistics for the Lake States, 1945. Lake States Forest Experiment Station, Station Paper No. 1, September 1946.

CONDITIONS AFFECTING GROWTH

Jack pine in the Lake States grows under a variety of conditions. The better the conditions, the higher the growth. Different soils - even the poorer sands - differ in moisture conditions and vary in fertility. In other words, there are variations in site quality. Different stands, again, vary in age, density of stocking, vigor, and merchantability. All these factors affect the rate of growth and consequently the production of wood volume per acre. While site and age are conditions over which we have no control, vigor, growing space, and merchantability can be improved through proper management.

Site

When foresters speak of site, they usually mean the productive capacity of the habitat. The better the site, the larger the trees and the higher the volume production per unit of area at a given age. In well-stocked stands, where the space is fully occupied, volume production is dependent almost entirely on the quality of site.

The accepted index of site quality is the relationship between age and the average height of dominant trees in the stand. The average height attained by the dominant and codominant trees within a given period of time is referred to as "site index." For jack pine, this period is 50 years. Although the relationship between the average volume per tree and age is a better indicator of site quality, it is easier to measure height than to determine volume.

The trends of height, diameter, and average volume over age have already been determined in conjunction with yield studies made by the Lake States Forest Experiment Station in well-stocked jack pine stands over the entire region.4/ These trends (table 1) and the normal yields (table 2) are used for the purpose of classifying site-index-growth capacities of jack pine on various soils. The trends are particularly applicable to even-aged and fully stocked stands since they were determined for such stands.

These tabulations show the relative productivity of different sites. The trends in table 1 indicate, for example, that the average jack pine tree on good sites contains about 60 percent more merchantable volume than the average tree on medium sites. The average tree on medium sites, in turn, contains more than twice as much volume as its counterpart on poor sites. The productivity on good sites, in other words, is more than three times as high as that on poor sites. The productivity on a very poor site, furthermore, is only about one-eighth of that on a good site. This site advantage is practically the same at all ages. Considering the fact that jack pine generally occupies poorer soils, this wide range in productivity is rather striking.

4/ The material referred to in this paper is drawn in part from "Management of Jack Pine Stands in the Lake States" by F. H. Eyre and R. K. LeBarron, U. S. Dept. of Agr. Technical Bul. #883, February 1944.

Table 1.--Height of dominant trees, average diameter and average volume per tree as indexes of site quality for jack pine.
(Fully-stocked stands)

Age of stands	Ave. ht. of dominants	Ave. stand diameter	Ave. vol. per tree 1/	Ave. ht. of dominants	Ave. stand diameter	Ave. vol. per tree 1/
	Good site (site index: 66)			Medium site (site index: 53)		
Years	Feet	Inches	Cu.ft.	Feet	Inches	Cu.ft.
20	30	4.3	.60	22	3.7	.35
30	44	6.3	2.40	35	5.4	1.43
40	56	8.0	5.12	45	6.8	3.10
50	66	9.3	8.25	53	7.9	5.02
60	75	10.4	11.25	60	8.8	6.86
70	81	11.4	14.10	65	9.6	8.45
80	86	12.2	16.35	69	10.2	10.00
	Poor site (site index: 40)			Very poor site (site index:30)		
20	17	3.0	.15	11	2.0	.08
30	27	4.4	.64	18	3.2	.20
40	34	5.4	1.47	25	4.0	.54
50	40	6.2	2.39	30	4.6	.99
60	45	6.9	3.18	33	5.1	1.41
70	49	7.5	4.00	36	5.6	1.80
80	52	8.0	4.50	38	6.0	2.00

1/ Gross volume, excluding bark, of trees 5 inches and larger in d.b.h. to a top diameter of 3 inches inside bark.

Table 2.--Yields per acre of fully-stocked stands of jack pine in the Lake States by different sites.

Age of stands (Yrs.)	Good site (site index: 66) Yield per acre: Merch. cu.ft. 1/	Board feet 2/: Scribner rule	Board feet 2/: Int. 1/4"rule	Current annual growth-cu.ft.	Medium site (site index: 53) Yield per acre: Merch. cu.ft. 1/	Board feet 2/: Scribner rule	Board feet 2/: Int. 1/4"rule	Current annual growth in cu.ft.
20	795	....	....		595	....	....	
				81				66
30	1605	900	1150		1250	500	650	
				63				52
40	2230	2250	2800		1770	1150	1500	
				41				36
50	2640	3900	4800		2135	2100	2650	
				23				19
60	2870	5650	6850		2330	3050	3750	
				9				3
70	2960	7300	8700		2360	3900	4800	
				-2				-16
80	2940	8400	9900		2200	4250	5150	

Age of stands (Yrs.)	Poor site (site index: 40) Yield per acre: Merch. cu.ft. 1/	Board feet 2/: Scribner rule	Board feet 2/: Int. 1/4"rule	Current annual growth-cu.ft.	Very poor site (site index: 30) Yield per acre: Merch. cu.ft. 1/	Board feet 2/: Scribner rule	Board feet 2/: Int. 1/4"rule	Current annual growth in cu.ft.
20	350	....	....		....	....	....	
				52				37
30	800	....	....		370	....	....	
				43				30
40	1230	....	....		670	70	100	
				29				3
50	1520	800	1050		700	140	200	
				10				-60
60	1620	1150	1450		100	30	40	
				-16				
70	1460	1280	1600		....	....	.....	
				-70				
80	800	800	1000		....	....	....	

1/ Cubic-foot volume is the gross volume, excluding bark, of trees 5 inches and larger in d.b.h., to a top diameter of 3 inches inside bark.

2/ Board-foot volume is the net volume of trees 9 inches and larger in d.b.h. Top diameters are variable, the minimum being 6 inches inside bark.

The proportion of jack pine area by sites in the Lake States is estimated by the Forest Survey to be about as follows:

State	Total area	Distribution by sites		
		Good site	Medium site	Poor site
	M acres	Percent		
Minnesota	1,240	20	60	20
Wisconsin	764	15	50	35
Michigan	1,085	10	45	45
Region	3,089	15	52	33

Although the relationship between the known soil types and the site index has not yet been definitely established, observations 5/ seem to indicate that better jack pine sites are most commonly found on Cass Lake, Plainfield, and Vilas fine sands; Kinghurst, Marquette, Rockwood, Sebeka sandy loams, and Vesper fine sandy loam. Such soils as Plainfield sand, Boone fine sand, Menahga and Nymore loamy sands support predominantly jack pine of medium site quality. Poor soils such as Grayling, Menahga, and Sparta sands usually indicate poor sites.

Soil moisture is probably one of the factors which most affects the growth of jack pine. A water table within 3 to 7 feet of the soil surface at midsummer causes jack pine to grow better on sands. It may make the difference of one site class. More fertile fine sands and loamy sands, as a rule, have high water-holding capacities and, therefore, nearly always show high site indexes. Soil fertility and the depth and the condition of the humus layer also greatly contribute to the productivity of the site.

It is obvious, therefore, that in order to estimate future yields of jack pine stands it is necessary first to determine the quality of the site.

Age

A relatively short-lived species, jack pine on average sites generally is considered mature when 70 years of age. On poor sites this age may be lower. After the age of 50, the volume increment becomes progressively smaller as a result of slower growth and mortality. This can be observed from the trend of yields per acre shown for different sites in tables 2 and 3.

The current growth on medium sites, for example, starts out as high as 66 cubic feet per acre per year between ages 20 and 30 and declines progressively as the stands get older. Between ages 50 and 60, the growth is reduced to 19 cubic feet; after 70 years the growth becomes negative because of the increased mortality associated with old age. Decimation progresses rapidly, especially after 80 years of age. Hardly any fully stocked stands can be found on medium site after 80 years of age.

5/ Eugene I. Roe. Forest Soils - The Basis of Forest Management. Lake States Forest Experiment Station, August 1935. (Mimeographed)

Table 3.--Number of trees, basal area, and space per tree as measures of full stocking in jack pine by different sites.

Age of stands	Good site (Site index: 66) No. of trees per acre	Basal area	Average space per tree	Space per sq. ft. of B.A.	Medium site (site index: 53) No. of trees per acre	Basal area	Average space per tree	Space per sq.ft. of B. A.
Years		Sq.ft.	Sq.ft.			Sq.ft.	Sq.ft.	
20	1320	133	33	327	1700	128	26	340
30	670	146	65	298	875	140	50	311
40	435	150	100	290	570	143	76	305
50	320	152	136	287	425	144	102	303
60	255	151	171	288	340	142	128	307
70	210	149	208	293	280	138	155	316
80	180	144	242	302	220	127	199	343
	Poor Site (site index: 40)				Very poor site (site index: 30)			
20	2365	119	18	366	3800	83	11	525
30	1245	131	35	333	1850	104	23	419
40	840	134	52	325	1250	109	35	399
50	635	135	69	322	710	82	61	532
60	510	132	85	330	70	10	620	4356
70	375	115	116	379	....	...	...	
80	178	62	245	702	....	...	...	

Longevity and site quality seem to go hand in hand. On very poor sites, only a few trees can be expected to survive until age 60. On poor sites, out of 510 trees per acre which represent full stocking at age 60, only 178 trees survive until age 80. The decline is also noticeable on medium sites after age 70. Only good sites are able to maintain full stocking at age 80. For pulpwood production, jack pine should not be held beyond 50 or 55 years of age on average sites.

In the case of sawlog production, the situation is quite similar. From table 2, it is apparent that only medium and good sites should be considered for board-foot production. Only a few trees, 9 inches and larger in d.b.h., can be found on very poor sites even at age 50; at age 70 to 80, the entire stand will be gone. On poor sites, the maximum yield of 1,280 board feet, Scribner, per acre at age 70 is too low to be of much commercial importance, especially since it is made up of very small-size logs.

Many mistakes in management can be attributed to the fact that unfavorable conditions of poor site and old age had not been fully recognized.

Stocking

In addition to site quality and age, the density of a stand, or the number of trees per acre, has a very important bearing on the expected yield of forest products. Fully stocked stands occupy only a small portion of the total area classified as jack pine type. Occasionally one finds dense thickets which are noticeably overstocked. Predominantly, however, throughout the Lake States jack pine stands are definitely understocked.

Table 3 presents number of trees per acre, 0.6 inch or larger, d.b.h., total basal area of stems at breast height, average space per tree, and the space required to produce one square foot of basal area as different measures of normal or good stocking. A normal or fully stocked stand is one in which the trees fully utilize the crown space so that no large openings are found. However, it allows considerable suppression which is gradually reduced through natural thinning or mortality. The proportion of dominant and codominant trees in a fully stocked stand in relation to the average stand diameter is about as follows:

Average stand diameter	Proportion of dominant and codominant trees in the stand
Inches	Percent
2	51.2
3	56.1
4	60.9
5	64.8
6	69.0
7	74.8
8	78.8
9	81.4

The growing space per tree controls stand development. It affects diameter growth, height growth, tree form, and merchantability and, consequently, the yield of merchantable wood per acre. From the point of view of growth and development, this space may be insufficient, excessive, or adequate. In overstocked stands, the growing space per tree is too small for normal production of merchantable wood. Such stands, although appearing fully stocked, are actually stagnant. The growing space in understocked stands, on the other hand, is excessive, and much of it is wasted in the form of large openings. Such stands produce a large number of "orchard" type trees which are short and limby. In a well-stocked stand of medium site quality, about 305 square feet ($17\frac{1}{2}$ x $17\frac{1}{2}$) of space are needed (table 3) to produce one square foot of basal area. The younger the stand, the greater the number of stems per square foot of basal area. The better the site, the less space is required per square foot of basal area.

For better determination of stocking, both number of trees and total basal area should be considered. Some stands may be slightly understocked in number of trees but actually have enough basal area to give good stocking.

Another numerical expression of density can be made in terms of height. In well-stocked stands, the average spacing of trees bears a definite relation to the average height of the stand. In normal jack pine stands, for example, average spacing is about 20 percent of the average height of the dominant and codominant trees.6/ This is a good rule-of-thumb for judging normal stocking. This spacing varies somewhat with age and site as shown in table 4.

The application of this "percent-height" rule is very simple. If a 40-year-old jack pine stand, whose average height of dominants is 45 feet (indicating medium site), contains 570 trees per acre, it should be considered normal since the average spacing in this case is $\sqrt{\frac{43560}{570}}$ = 8.7 feet or 19 percent of the dominant height (see table 4). Should the stand contain only 303 stems per acre instead of 570, a much wider spacing would be indicated, namely $\sqrt{\frac{43560}{303}}$ = 12 feet, which is about 27 percent of the dominant height. If a 40-year-old stand (medium site), on the other hand, is found to contain as many as 500 dominant stems per acre, it should be regarded as overstocked, since the average spacing of these dominants is $\sqrt{\frac{43560}{500}}$ = 9.3 feet or 21 percent of the average height, which is somewhat less than the 23 percent shown in table 4.

6/ F. G. Wilson. Numerical Expression of Stocking in Terms of Height. Jour. of Forestry, Vol. 44, p. 758. October 1946.

S. R. Gevorkiantz. More about Numerical Expression of Stocking in Terms of Height. Jour. of Forestry, Vol. 45, p. 203. March 1947.

Table 4.- Spacing of trees in normal jack pine stands expressed in percent of average height of dominant and codominant trees

Age of stand	Good site (S.I.:66)		Medium site (S.I.:53)		Poor site (S.I.:40)	
	Total stand	Dominant stand	Total stand	Dominant stand	Total stand	Dominant stand
Years	Percent of average height of dominants					
10	21	30	27	38	30	43
20	19	24	23	30	25	34
30	18	22	20	25	22	28
40	18	20	19	23	21	26
50	18	19	19	22	21	24
60	17	19	19	21	20	23
70	18	19	19	22	22	24
80	18	19	20	23	30	34

The growth of understocked stands does not bear the same relation to yield-table growth as total basal area (or volume) bears to the yield-table value. On the basis of special studies of approach of understocked stands of jack pine toward normality, it was possible to obtain a series of correction factors 1/ which are presented below:

Present stocking (percent of normal)	Growth rate (next 10-year period) in percentage of normal
10	15.4
20	29.6
30	42.6
40	54.4
50	65.0
60	74.4
70	82.6
80	89.6
90	95.4
100	100.0

1/ S. R. Gevorkiantz and William A. Duerr. Methods of Predicting Growth of Forest Stands in the Forest Survey of the Lake States. Lake States Forest Experiment Station Economic Note No. 9, April 1938.

As an example of the use of these converting factors, take a stand on medium site which is 40 years old and only 50 percent stocked. Reference to table 2 shows that a fully stocked stand of age 40 on average site contains 1,770 cubic feet per acre and in 10 years will grow

$$2135 - 1770 = 365 \text{ cubic feet.}$$

On the basis of the tabulation above, the growth of the stand 50 percent stocked is not 50 percent of 365 or 182 cubic feet but 65 percent of 365 or 237 cubic feet, or 23.7 cubic feet per acre per year.

Vigor

The vigor of a tree is influenced not only by age and site quality but also by its relation to the surrounding trees, its position in the stand, and the density of its crown. That vigor, defined as a degree of dominance, is a reliable index of growth was shown by the increment in diameter and volume of 2,210 jack pine trees growing in a 30-year-old stand on a better than medium site in three permanent sample plots near Cass Lake, Minnesota. The result summarized in table 5 shows a distinct downward growth trend from progressive or vigorous to regressive or less vigorous trees and also brings out the importance of crown density. The trees were classified at the close of the 10-year period for which growth is shown.

Table 5 shows that one strong dominant tree can grow as much wood as three weak ones, indicating that fully stocked yields can also be produced by a smaller number of carefully selected trees.

Soundness and Form

While vigor is of paramount importance to tree growth, soundness is an important modifier of a tree's volume and value. Ordinarily the most vigorous trees are sound, but this is not always true. The kind and amount of defect or injury in a tree greatly influences its development and value in the stand. Rot is most serious where past fires have caused butt scars on the trees thus providing entrance for fungi.

Likewise the usefulness of a tree for certain types of products depends on the form or shape of the stem and crown as well as on soundness.

To sum it all up, it is apparent that growth of jack pine is a reflection of its environment. The better the conditions, the better the growth. Through a knowledge of these conditions one can predict the future yield of any stand. Under favorable conditions, jack pine will yield in 50 years more than any other Lake States species found on the same soil.

Table 5.--Average 10-year increment in diameter and volume of 30-year-old jack pine by vigor classes 1/

Vigor class		Average growth in d.b.h.	Volume growth per tree	Basis trees
Position	Crown density			
		Inches	Cu. ft.	No.
Head dominant	Good	2.0	3.18	520
Do	Medium	1.7	2.61	121
Strong dominants	Good	1.5	1.89	693
Do	Medium	1.1	1.10	5
Conditional dominants	Good	1.3	1.47	120
Do	Medium	1.0	1.40	98
Do	Poor	0.9	0.99	314
Weak dominants and codominants	Poor	0.5	0.65	326
Intermediates	Poor	0.3	0.24	113
				2,210

1/ S. R. Gevorkiantz, F. O. Rudolf, and F. J. Zehngraff. A tree classification for aspen, jack pine and second-growth red pine. Journal of Forestry.